

# **A DEVICE AND METHOD FOR SOLDERING CONTACTS ON SEMICONDUCTOR CHIPS**

## **CROSS-REFERENCE TO RELATED APPLICATION**

This application is a continuation of International Patent Application Serial No. PCT/DE02/03506, filed September 19, 2002, which published in German on April 10, 2003 as WO 03/030246, and is incorporated herein by reference in its entirety.

## **FIELD OF THE INVENTION**

The present invention relates to a device for soldering contacts especially on vertically integrated semiconductor chips.

## **BACKGROUND OF THE INVENTION**

In the three-dimensional integration of semiconductor chips, a number of levels of thinned chips are adjusted on one another and electrically connected. Component placement takes place in an automatic placement machine in which the individually separated chips are placed in an adjusted manner onto a wafer. The surfaces of the wafer and of the chips have surfaces that are structured with contact areas in mirror-image patterns in relation to one another, so that the contacts belonging to one another can be applied with great accuracy such that they fit on one another. The surface of the wafer consists for example of bare copper, that of the chips for example of tin or a low-melting tin alloy. In the case of this process, the problem arises that the bare metal surfaces, especially the copper surface, oxidize because of the high process temperatures. An oxidation layer, however, prevents reliable contacting.

Soldering methods for the soft-soldering of copper surfaces with lead-tin-based solders are known and work very reliably. In these cases, the thicknesses of the solder layers lie in the range of 100  $\mu\text{m}$ . During the heating operation, the surfaces are flushed with forming gas, the reactive fraction of which prevents oxidation. A soldering technique which is known by the terms "isothermal solidification" or SOLID uses extremely thin solder layers of less than 5  $\mu\text{m}$

in thickness. In the case of this soldering method, complete alloying of the solder metal with the adjoining metal surfaces occurs during the soldering operation, accompanied by the formation of intermetallic phases, whereby the melting point rises and the solder melt isothermally solidifies. While thin oxide layers may break up when a thicker solder layer is used, so that adequately good contacting can be established, even a thin oxide layer is enough to completely prevent wetting of the metal surface with a very thin layer of the solder material.

An especially important requirement in the case of the SOLID soldering method is that the metal surfaces which are being soldered to one another remain completely free of oxide. Therefore, it is necessary to achieve a situation in which as little atmospheric oxygen as possible gets into the atmosphere of forming gas surrounding the wafer during the heating operation. For this purpose, the forming gas must enclose the chip region to be heated as impenetrably as possible. However, this cannot take place completely, since both surfaces must be freely accessible during the adjustment.

GB 2244374 A describes a device for soldering contacts on vertically integrated semiconductor chips in which a clamping device, a flushing device, a chip mount and a heater are provided. DE 198 50 595 A1 and DE 195 04 967 A1 disclose methods of producing chip-carrier connections in which the solder points are heated from the rear side of the chip.

DE 197 47 846 A1 disclosed a method of contacting components, in particular for connecting a semiconductor chip to a leadframe, in which isothermal solidification is used. A silicon chip can be connected to a silicon substrate in the way described. The connection of the contacts applied to the subelements takes place by means of an intermediate layer, which is melted by supplying vibrational energy, and the connection is established by isothermal solidification. Thermal support for this operation may be provided, since the reaction is expediently carried out at elevated temperature under inert gas.

## SUMMARY OF THE INVENTION

An object of the invention is to specify a device and a method for soldering contacts on semiconductor chips with which extremely thin metal areas can be soldered to one another in

air at approximately 300°C without the occurrence of oxidation, which prevents a durable electrically conducting connection from being established, during the heating operation. In particular, it is also intended to prevent unprotected areas that are present alongside the metal areas to be soldered from oxidizing.

A device according to the invention is provided with a heater which is designed in such a way that a chip held on a chip mount above a clamping device (chuck) of an automatic placement machine can be heated from a side of the chip facing the chip mount at least to such a degree that a solder applied to the opposite side of the chip, facing the clamping device, is melted. There is also a flushing device, which has a plate with a window, a gas channel for forming gas and a gas outlet opening arranged at the window. This plate is fitted above the clamping device, aligned parallel to the transporting area intended for the wafer. The chip mount is vertically movable in relation to the transporting area of the clamping device, so that the chip can be brought as near as desired to a wafer arranged on the transporting area and, in particular, can be pressed onto the wafer with a pressing pressure which is provided or can be set.

This device also allows implementation of a method according to the invention, in which a solder is applied to the contact of the chip, the contacts are flushed with a forming gas, the solder is melted, in that the chip is heated from a side facing away from the contact, until the melted solder forms a layer of a thickness of less than 5  $\mu\text{m}$  the contacts are pressed onto one another and the solder is cooled to such an extent that it undergoes an isothermal solidification.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

The description of a preferred exemplary embodiment of the device according to the invention, which also allows the method according to invention to be performed, follows on the basis of Figures 1 and 2.

Figure 1 shows a diagram of an example of the device according to the invention in cross section.

Figure 2 shows an enlarged representation of the chip mount with the heat sources as a diagram.

### **DETAILED DESCRIPTION OF THE PREFERRED MODE OF THE INVENTION**

In Figure 1, the device is represented in cross section. Shown in this example is an automatic placement machine with a clamping device 1, usually referred to as a chuck, which is provided on a transporting area with a transporting device for receiving and transporting a wafer 2, on which the semiconductor chips are to be placed. The wafer is positioned on the chuck with the oxide-free copper surface upwards. Represented in Figure 1 are chips 3, which have already been soldered on the wafer, and also a further chip 4, which is to be soldered on in the next operation. This chip 4 is brought over the wafer on a chip mount 13 and is held, for example under a suction channel of the chip mount, by a negative pressure induced in the chip mount.

Arranged over the transporting device of the chuck is a flushing device 5, which is essentially formed by a plate 6 with a window 7, a gas channel 8 and a gas outlet opening 14, arranged at the window. This plate is fitted parallel to the transporting area and the wafer arranged there or is fixed in this position at least during the placement operation. The wafer is transported through under the window 7 of this plate, so that the next chip 4 in each case can be placed from above through the window onto the region of the wafer located under the window 7. For this purpose, the chip mount 13 need only be moved in the vertical direction.

The plate 6 is positioned as close as possible above the surface of the wafer. The gas outlet opening 14 is located as close as possible to the window, so that a forming gas supplied through the gas channel 14 directly reaches the region of the wafer on which components are to be placed. In the case of the configuration represented in Figure 1, the forming gas exits mainly in the window 7 of the plate. The remaining part of the forming gas flows in the radial direction from the outer edge of the plate and prevents ambient air from being sucked in. An oxygen-deficient cloud 9 of forming gas, which is indicated in the drawing by an arcuate dotted line, forms in the region above the window. The formation of this oxygen-deficient zone may

be enhanced by an additionally fitted annular diaphragm 10, at the upper edge of which the gas can possibly also be sucked away if need be.

At the edge of the plate 6 there is preferably a further gas channel 11, via which cooling air can be supplied, blowing against the wafer in the outwardly pointing radial direction through the correspondingly arranged further gas outlet opening 15. The further gas outlet opening 15 is formed, for example, by a number of nozzles fitted around the edge of the plate, which are directed outwards, so that the air exits outwards parallel to the surface of the wafer. A radial stream of the cooling gas is to be preferred by far over a direct alignment of the gas stream onto the wafer. With a radial gas stream, the radial flow of the forming gas under the plate 6 is also enhanced.

If the chip 4 to be soldered on is lowered by vertical movement of the chip mount 13 downwards onto the wafer 2, it enters the oxygen-deficient cloud 9. In this position, the chip mount 13 comes into the region where a thermal radiation source 12, which in this exemplary embodiment is formed by a laser radiation source, is coupled in. Consequently, the chip 4 is heated from its rear side facing away from the wafer to such a degree that the solder material on the front side melts and the contact connection in relation to the copper surface of the wafer can thus be established.

It is favourable if the layer of low-melting solder is applied to the contacts of the chip 4 and not to the contacts of the wafer to be soldered to the latter, since better heat contact through the chip to the solder layer is achieved in this way. The heating of the chip in this way leads immediately to the melting of the solder material, which solidifies in a fraction of a second on contact with the colder copper layer of the wafer.

In Figure 2, an exemplary embodiment of the chip mount 13 is shown in cross section. A lower planar area for receiving the chip 21 has openings 20 around the edge, which are connected to a channel. Consequently, the chip 21 is sucked into place. For this purpose, a suction connection piece 27 is connected to a suitable pump or some other device for generating a negative pressure. Fitted within the chip mount is a body 23 which is permeable

to infrared radiation. Through this body, the thermal radiation can reach the rear side of the chip sucked into place. The body 23, which may be made of quartz glass for example, is also suitable for transferring the mechanical pressing pressure of typically 3.5 bar to the chip. To transfer the force as uniformly as possible to the chip, there may be provided an additional, likewise infrared-permeable, preferably elastic and temperature-resistant layer 24, which may be silicon for example. The coupling-in of the thermal radiation takes place in this example via the metallic mirror 25, fitted obliquely in the chip mount 13, or via a metallicity mirrored prism, which reflects the thermal radiation towards the chip. Such a prism may also be integrated into the body 23.

The homogeneity of the temperature distribution over the chip area is not critical in principle. It just has to be ensured that the melting temperature of the solder material is exceeded everywhere on the contacts. In the interests of a short heating-up time, it is aimed for the chip area to be irradiated with the thermal radiation as uniformly as possible.

On the other hand, the maximum permissible temperature is limited only by the materials used. In principle, it is therefore adequate if only a point, which preferably lies in the centre of the chip, is heated. It is then expedient to wait a moment before the warm chip is brought into contact with the cold wafer. This avoids the solder material from being cooled prematurely before the heat has been able to spread laterally to an adequate extent.

If the heat is not to be irradiated onto only one point, it is possible by a diffuser or a suitable optical system to achieve the effect that the thermal radiation, for example the laser beam, is expanded in a suitable way such that the entire chip area is covered by it. Alternatively, the thermal radiation may be coupled into a light guide, which is coupled onto the chip mount 13 and guides the thermal radiation onto the chip. Such a light guide may replace the mirror 25 or the prism and the body 23. A halogen lamp 26 with a parabolic mirror may also be used instead of the laser radiation source 12 as a heat source. This is shown in Figure 2 by an alternative drawing.

In the case of particularly small chips with only a few mm<sup>2</sup> of surface area, the chip mount, then designed to be correspondingly small, may be subjected to radiation from outside and heated in its entirety. It is also possible for an at least partially metallically formed chip mount to be heated up by means of a heating coil, with which an eddy current is inductively generated in the metal, or else for the solder layer to be directly heated, in that the eddy currents are induced directly in the solder layer.

The lower area of the chip mount, intended for receiving a chip, may consist of a material which has adequate elasticity to permit lateral movements of the chip in the range of typically  $\pm 10 \mu\text{m}$ . Consequently, a self-centring of the two contact areas structured in mirror-image patterns in relation to one another is achieved on account of the surface tension of the melted solder layer.